# PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

REC'D 06 MAY 2004
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| Applicant's or agent's file reference<br>CR00548P C01 | **FOR FURTHER ACTION** | See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) |
| International application No.<br>PCT/EP 03/00596 | International filing date *(day/month/year)*<br>22.01.2003 | Priority date *(day/month/year)*<br>31.01.2002 |
| International Patent Classification (IPC) or both national classification and IPC<br>H04L5/02 | | |
| Applicant<br>MOTOROLA INC. et al | | |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

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| Date of submission of the demand<br>30.06.2003 | Date of completion of this report<br>05.05.2004 |
| Name and mailing address of the international preliminary examining authority:<br>European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Authorized Officer<br>Palacián Lisa, M<br>Telephone No. +49 89 2399-8265 |

**I. Basis of the report**

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

**Description, Pages**

| | |
|---|---|
| 1, 2, 6-16 | as originally filed |
| 3-5 | received on 22.04.2004 with letter of 16.04.2004 |

**Claims, Numbers**

| | |
|---|---|
| 1-12 | received on 22.04.2004 with letter of 16.04.2004 |

**Drawings, Sheets**

| | |
|---|---|
| 1/5-5/5 | as originally filed |

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:
   - ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   *(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

| | | | |
|---|---|---|---|
| Novelty (N) | Yes: | Claims | 1-12 |
| | No: | Claims | |
| Inventive step (IS) | Yes: | Claims | 1-12 |
| | No: | Claims | |
| Industrial applicability (IA) | Yes: | Claims | 1-12 |
| | No: | Claims | |

2. Citations and explanations

   **see separate sheet**

Reference is made to the following documents:

D1: BAUDAIS J-Y ET AL: 'AN IMPROVED LINEAR MMSE DETECTION TECHNIQUE FOR MULTI-CARRIER CDMA SYSTEMS: COMPARISON AND COMBINATION WITH INTERFERENCE CANCELLATION SCHEMES', EUROPEAN TRANSACTIONS ON TELECOMMUNICATIONS, EUREL PUBLICATION, MILANO, IT, VOL. 11, NR. 6, 1 NOV. 2000, PAGE(S) 547-554

D2: KALOFONOS D N ET AL: 'Performance of the multi-stage detector for a MC-CDMA system in a Rayleigh fading channel', GLOBAL TELECOMMUNICATIONS CONFERENCE, 1996. GLOBECOM '96. 'COMMUNICATIONS: THE KEY TO GLOBAL PROSPERITY LONDON, UK 18-22 NOV. 1996, NEW YORK, NY, USA, IEEE, US, PAGE(S) 1784-1788

D3: BURY A ET AL: 'Block transmission equalizers using constrained minimum variance filters with application to MC-CDMA', VOL. 1, 06-08 SEPT. 2000, PAGE(S) 159-163

D4: HÉLARD J-F ET AL: 'Linear MMSE detection technique for MC-CDMA', ELECTRONICS LETTERS, IEE STEVENAGE, GB, VOL. 36, NR. 7, 30 MARCH 2000, PAGE(S) 665-666

D5: GINIS G ET AL: 'ON THE RELATION BETWEEN V-BLAST AND THE GDFE', IEEE COMMUNICATIONS LETTERS, IEEE SERVICE CENTER, PISCATAWAY, US, US, VOL. 5, NR. 9, SEPT. 2001 PAGE(S) 364-366

**Re Item V**

**Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. The application relates to a method of decoding a received spread OFDM wireless communication signal (claim 1) and the corresponding receiver (claim 7). The received spread OFDM signal is equalized and a decision function is performed and afterwards is split into a number of portions (s1, s2, s3, s4).

1.1 D1, considered as the closest prior art, discloses such a method and receiver.

1.2 The problem to be solved by the present invention may be regarded as to provide an efficient and less complex algorithm for decoding a spread OFDM signal than the prior art method of successive interference cancellation.

1.3 The problem is solved by the features included in the characterizing portion of the independent claims: for each portion (e.g. s1) a signal derived from the other portions (e.g. s2, s3, s4) is subtracted from the received signal and the result is equalized and decided to produce a further processed portion thereby reducing interference due to the other portions. This step is repeated for each of the other portions.

2. None of the prior-art documents cited in the International Search Report provides this solution or gives a hint to it. D1 deals with multiuser interference and parallel or successive interference cancellation to deduct the decisions made for the strongest user from the received signal and so on. D2 also deals with multiuser interference proposing an algorithm with a high computing load. D3 teaches to perform a linear estimation to calculate a decision symbol. D4 is concerned primary with the equalization of single users embedded into an MC-CDMA signal. D5 discloses the V-BLAST algorithm requiring a high computational complexity. Any of the methods/receivers taught by of these documents divides the equalized and decided signal into portions and calculates a new portion by computing a new difference signal calculated by subtracting a combination of the other portions from the received signal thereby obtaining a significant less complex method and receiver.

3. Therefore, claims 1 and 7 meet the requirement of Article 33 PCT.

4. Claims 2-6 and 8-12 are dependent on claims 1 and 7 respectively and as such also meets the requirements of the PCT with respect to novelty and inventive step.

for multiple antennas systems in the publication by G.J. Foschini and M.J. Gans, "On Limits of Wireless Communications in a fading Environment when Using Multiple Antennas", *Wireless Personnal Communications* 6:311-335, 1998. However, it has been demonstrated (in the publication by P. Loubaton, M. Debbah and M. de Courville, "Spread OFDM Performance with MMSE Equalization", in *International Conference on Acoustics, Speech, and Signal Processing*, Salt Lake City, USA, May 2001) that V-BLAST algorithms are not suited for conventional SOFDM systems due to the averaging of the SNRs (signal/noise ratios) at the receiver across the carriers during the despreading step. Moreover, such approaches lead to a tremendous decoding complexity due to the computation of several pseudo inverse matrices.

A need therefore exists for an OFDM communication system and decoding algorithm for use therein wherein the abovementioned disadvantage(s) may be alleviated.

**Statement of Invention**

The present invention provides a method of decoding a received spread OFDM wireless communication signal, and a receiver comprising decoding means for decoding a received signal by such a method, in a spread OFDM wireless communication receiver, as described in the accompanying claims.

In one embodiment of the present invention, the decoding algorithm comprises splitting a received block into two equal parts, one of the parts being decoded first and then subtracted from the received vector to suppress part of the interference and the other of the parts being decoded next. This iterative procedure can be further extended by successive block splitting and results in a multi-resolution decoding algorithm. An attractive property of this algorithm is that although it still relies on the computation of pseudo-inverses, the expressions of these pseudo-inverses are easy to derive and may consist simply in the product of a diagonal matrix by a Walsh Hadamard transform. Thus, using Walsh Hadamard spreading sequences, the inherent complexity penalty of a V-BLAST decoding schemes is simply removed. This allows a significant gain in performance (e.g., around 3-4dB compared to MMSE SOFDM) with only a modest increase in complexity, which motivates:

i) the use of such new modulation schemes in practice and

ii) their proposal as a solution for future wireless LAN standards.

The following technical merits of the multi-resolution decoding algorithm of this embodiment of the present invention can be highlighted:

- Low arithmetical complexity compared to existing SIC BLAST techniques with same or better performance.
- Flexibility and scalability of the method (it is possible to adjust the number of iterations to be

performed based on a performance/complexity tradeoff).

- Can be combined into all OFDM standards as a proprietary transmission mode (since it can be

**Claims**

1. A method of decoding a received spread OFDM wireless communication signal comprising:
performing an equalizing and decision function on the received spread OFDM signal ($y$),
splitting the equalized and decided spread OFDM signal block ($\hat{s}$) into a number $2^i$ of portions ($\hat{s}_1$, $\hat{s}_2$, $\hat{s}_3$, $\hat{s}_4$), where i is positive integer;
characterised by:
for each of said portions ($\hat{s}_1$) of the equalized and decided signal block in turn subtracting values ($M\begin{bmatrix}0\\ \hat{s}_2\\ \hat{s}_3\\ \hat{s}_4\end{bmatrix}$) derived from the other portions ($\hat{s}_2$ to $\hat{s}_4$) of the equalized and decided signal block from the received signal block ($y$) to produce a respective difference signal; and
performing an equalising and decision function on the respective difference signal to produce a further processed equalized and decided portion ($\hat{\hat{s}}_1$) of the received signal in which interference due to the other portions ($\hat{s}_2$ to $\hat{s}_4$) of the equalized and decided signal block is substantiallyreduced;
the steps of producing the respective difference signal and performing the equalising and decision function to produce the further processed equalized and decided portion being repeated for each of the other portions ($\hat{s}_2$, $\hat{s}_3$, $\hat{s}_4$) of the signal block.

2. A method as claimed in claim 1 wherein repeating subtracting the values derived from other portions of the equalized and decided signal block from the received signal to produce a respective further difference signal comprises subtracting values derived from at least one of said further processed portions ($\hat{\hat{s}}_2$ to $\hat{\hat{s}}_4$) of the received signal from the received spread OFDM signal ($y$).

3. A method as claimed in claim 1 or 2 further comprising iterating processing the signal block, including iterating the steps of producing the respective difference signal and performing the equalising and decision function to produce the further processed equalized and decided portion with values derived from the further processed portions ($\hat{\hat{s}}_1$ to $\hat{\hat{s}}_4$) in place of previously processed portions ($\hat{s}_1$ to $\hat{s}_4$), to recover still more reliable estimates for each of the portions.

4. A method as claimed in claim 3 wherein iterating processing the signal block includes splitting the equalized and decided spread OFDM signal block ($\hat{s}$) into a number $2^j$ of portions ($\hat{s}_1$ to $\hat{s}_4$), where j is a positive integer greater than i so that iterating the steps of producing the respective difference signal and performing the equalising and decision function to produce the further processed portion is performed with a greater number of portions than the previous steps.

5. A method as claimed in any preceding claim wherein said equalizing steps comprise multiplying by a first diagonal matrix having elements dependent on channel coefficients; and multiplying by a second matrix which is a subset of a Walsh Hadamard matrix.

6. A method as claimed in any preceding claim wherein said equalizing steps comprise performing minimum mean square error equalization.

7. A receiver (160-180) for use in a spread OFDM wireless communication system (100), the receiver comprising means for receiving a spread OFDM wireless communication signal, and decoding means for decoding the received signal by a method as claimed in any preceding claim, said decoding means comprising:
equalizing and decision means for performing said equalizing and decision function on the received spread OFDM signal ($y$),
means for splitting the equalized and decided spread OFDM signal block ($\hat{s}$) into a number $2^i$ of portions ($\hat{s}_1$, $\hat{s}_2$, $\hat{s}_3$, $\hat{s}_4$), where i is positive integer;
characterised by:
subtracting means for subtracting, for each of said portions ($\hat{s}_1$) of the equalized and decided signal block in turn, said values ($M\begin{bmatrix}0\\\hat{s}_2\\\hat{s}_3\\\hat{s}_4\end{bmatrix}$) derived from the decided other

portions ($\hat{s}_2$ to $\hat{s}_4$) of the equalized and decided signal block from the received signal block ($y$) to produce a respective difference signal;

said equalizing and decision means being arranged to perform said equalising and decision function on the respective difference signal to produce said further processed equalized and decided portion ($\hat{\hat{s}}_1$) of the received signal in which interference due to the other portions ($\hat{s}_2$ to $\hat{s}_4$) of the equalized and decided signal block is substantially reduced;

and said decoding means being arranged to repeat, for each of the other portions ($\hat{s}_2$, $\hat{s}_3$, $\hat{s}_4$) of the signal block, said steps of producing the respective difference signal and performing the equalising and decision function to produce the further processed equalized and decided portion.

8. A receiver as claimed in claim 7 wherein said subtracting means is arranged so that repeating subtracting the values derived from the other portions of the equalised and decided signal block from the received signal to produce a respective further difference signal comprises subtracting values derived from at least one of said further processed portions ($\hat{\hat{s}}_2$ to $\hat{\hat{s}}_4$) of the received signal from the received spread OFDM signal ($y$).

9. A receiver as claimed in claim 7 or 8 wherein said decoding means is arranged to iterate processing the signal block, including iterating the steps of producing the respective difference signal and performing the

equalising and decision function to produce the further processed equalized and decided portion with values derived from the further processed portions ($\hat{\hat{s}}_1$ to $\hat{\hat{s}}_4$) in place of previously processed portions ($\hat{\hat{s}}_1$ to $\hat{\hat{s}}_4$), to recover still more reliable estimates for each of the portions.

10. A receiver as claimed in claim 9 wherein said decoding means is arranged so that iterating processing the signal block includes splitting the equalized and decided spread OFDM signal block ($\hat{s}$) into a number $2^j$ of portions ($\hat{s}_1$ to $\hat{s}_4$), where j is positive integer greater than i so that iterating the steps of producing the respective difference signal and performing the equalising and decision function to produce the further processed portion is performed with a greater number of portions than the previous steps.

11. A receiver as claimed in any of claims 7 to 10 wherein said equalizing and decision means comprises matrix multiplication means for multiplying by a first diagonal matrix having elements dependent on channel coefficients and by a second matrix which is a subset of a Walsh Hadamard matrix.

12. A receiver as claimed in any of claims 7 to 11 wherein said equalizing and decision means comprises means for performing minimum mean square error equalization.